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COUNTRY REPORTS ON THE CURRENT STATUS AND ISSUES OF SURVEYING, CHARTING AND MAPPING AT THE NATIONAL LEVEL: NEEDS AND REQUIREMENTS VERSUS REALITY IN THE REGION

New techniques in Swedish official surveying and mapping

Paper submitted by Sweden**

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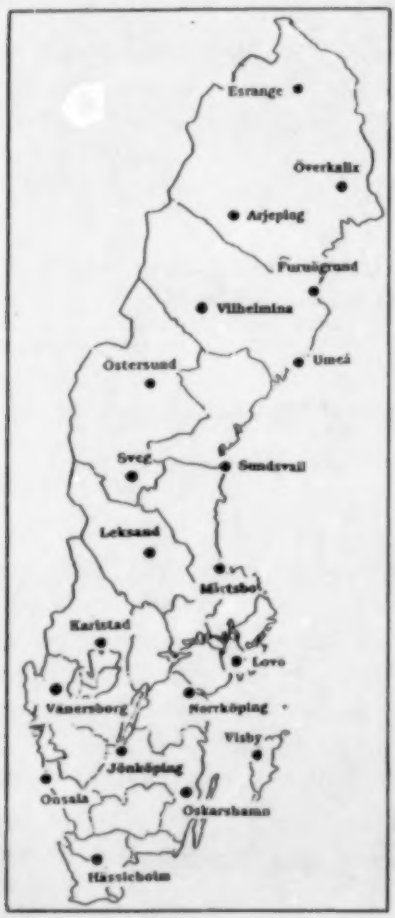
Introduction

During recent years it has been possible to introduce new techniques in Swedish official surveying and mapping activities. Thus in geodesy and photogrammetry GPS-based methods have been introduced. As far as map production concerns a completely digital production line has been implemented.

This paper gives an overview of the methods in question as well as some results.

GPS-based techniques

GPS-based techniques already play an important role in Swedish official surveying and mapping activities. Thus, GPS has been used for several years in densification of the national triangulation net. In this application GPS has now replaced traditional triangulation techniques based on electro-optical distance measurements and theodolite observations.



In order to support different GPS activities a network of permanent reference stations for GPS has now been established by NLS in cooperation with the Onsala Space Observatory, see figure 1. The basic idea is that this reference network is part of the official geodetic infrastructure, which i.a. means that costs for the establishment and maintenance of it, is covered by governmental funds.

Figure 1. The figure shows the Swedish network of permanent reference stations for GPS. The net consists of 20 stations. The average distance between stations is about 200 kms.

The purpose of the network is to

- provide both single- and dual-frequency data for relative GPS measurements
- provide differential corrections for broadcasting to real time users
- act as high-precision control points for Swedish GPS users
- study crustal dynamics

The network consists of 20 stations each permanently equipped with a GPS receiver. This means that the whole country is covered by this net. The average distance between the stations is about 200 kms.The stations are monumented with concrete pillars on bedrock. They can be used both for monotoring crustal movements, in particular the continuons land aplift, and for more prosaic production work. The stations are unmanned and steered through remote control from a control centre at NLS.

Observations at each reference station are normally made with 15 seconds interval and a 10 degree elevation mask. The daily observations are divided into eight sessions with three hours each. Thus the amount of raw data is almost 4 Mbytes per station a day. When using data for GPS supported aerial photo missions 1 second observations are taken. Data are transfered to the control centre via the tele network.

For post-processing, data from the reference stations are available for authorized users via a computerized Bulletin Board Service at NLS and via computer network. Daily status information of the reference stations is also available through the Bulletin Board Service.

The purpose of the reference network is to provide reference data continuosly for as many applications as possible, both carrier phase observations and pseudo-range corrections, in real time and for post-processing.

A very important application for the reference stations is in cadastral surveying. In the less densely populated parts of Sweden, which by the way is the main part, the connection of cadastral surveys to the national control network is often accomplished through approximate connections via orthophoto maps or land-use maps. This makes these measurements inappropriate to use in the geographical databases that is under construction at NLS and elsewhere today. GPS measurements to reference stations is thought to be the most cost-effective way to connect these cadastral surveys to the national control network in areas without control points.

During the last year a number of experiments using data from reference stations have been carried out by GPS users. One example is to determine the position of forest test areas. Another application is post-processing of carrier phase observations for positioning of drill-holes for geotechnical investigations.

Experiments show that it is possible to obtain a positioning accuracy at any point in the country on the decimetre level with the reference station net now established.

So far the network is not fully operational. The distribution of pseudo-range corrections and in the near future carrier phase data is today a major bottle-neck. We have not yet found an existing distribution system at a reasonable cost, that satisfy our requirements. However, the practical experiences gained in the operation of the network of reference stations will be very valuable for the final design of a fully operational twenty stations network.

GPS in aerial photography and photogrammetry

GPS techniques have also been introduced in our aerial photo activities as well as in photogrammetric block triangulation. The goals for the use of GPS technique in aerial photography at NLS are the following:

- to give information to the pilot about the position of the aircraft with respect to the planned photostrip i.e. to navigate
- to enable automatic exposures to be made in preselected positions
- to determine the position of the airborne camera at the time of exposure.

In 1989 experiments with Ashtech receivers were started in order to get a notion of the capability of GPS in aerial photography. A PC program for navigation and enabling automatic exposures in preselected positions was developed. GPS equipment has been mounted in our aircrafts since the air photo season 1991.

Now, GPS is used in all our photo missions in Sweden as well as abroad. As far as navigation is concerned this development has given the pilot a good and easy-to-use aid. The pilot is supported by a display unit, showing the position of the aircraft in relation to the planned photo strip. The equipment makes it easy to fly according to the photo plan and keep the flying altitude as planned.

GPS controlled shutter release also works with very good result. According to our experience 50% of all exposures are within 50 m from the predetermined position and almost all exposures within 100 m.

We have also carried out some experiments of making use of GPS determined camera positions in photogrammetric block triangulation. It is quite obvious that the use of GPS determined exposure stations makes it possible to reduce the geodetic control. From a pure technical point of view it is now possible to use this method in practical work. However, from an economic point of view it is clear that the new technique is not always justified. This very much depends upon the fact that the introduction of GPS in geodetic surveying makes it much less expensive to determine geodetic control points than earlier. This means that it is necessary to make a choice of method from case to case. In Sweden it is normally most economic to rely on traditional geodetic ground control in more populated areas and make use of GPS-determined camera station in mountainous and sparsely populated areas.

Digital Ortho Photos

Ortho photos play a very important role in Swedish map production. The production of the official maps at the scale of 1:10 000 and 1:50 000 is based on ortho photos. Ortho photos are also used for many other applications especially in forestry mapping.

During last years NLS has discussed the possibility to introduce digital ortho photos to the national map programme. NLS developed software for digital ortho photos already some seven years ago. However, at that time no user needs for digital ortho photos existed. Moreover it was not possible to put out high quality ortho photos on film material.

Now the conditions have changed. NLS has acquired a Barco 3800 laser plotter which is very suitable for output of digital ortho photos on film. Moreover some important users have announced their interest in digital ortho photos.

NLS last year carried out a pilot test with digital ortho photo map production. The test included the production of some 40 ortho photos. The production was based on scanning of aerial photo diapositives with a resolution of 25 microns. The digital ortho projection was carried out with an in-house developed software.

An important part of the pilot test was to study the possibility of using CD-R for delivery of digital ortho photos to customers. In order to reduce the amount of data the so called JPEG method was used to compress data. We found it possible to compress data by a factor 10 without loss of image quality. Thus a 50x50 cms digital ortho photo with a 0,1 mm pixel size could by compressed to some 2.5 Mbytes. This means that it is possible to store about 250 ortho photos on a compact disc. The pilot test showed it very simple to store digital ortho photos on a CD-R by using a PC, special software and a CD-writer.

As a result of this pilot test NLS has now started a full scale production of digital ortho photos. This digital production line for ortho photos has now been used for about half a year with good results. The aim is to produce some 1000 digital ortho photo map sheets during the fiscal year 1993/94.

NLS has recently presented to the Government the plans for the official mapping for the coming nine years. In this plan NLS suggested to supply ortho photos for the part of the country covered by the so called Economic Map by the year 2003. This means an annual production of some 1300 sheets. This idea has been well received by some of the present main users of GIS.

Digital production lines for official maps

Computer assisted techniques were first introduced in topographic map production in the late 1960's. However, it was not at that time possible to computerize all stages of production. Instead, a combined digital-manual production technique was adopted in which the computerized share was increased step by step.

In conjunction with the development of a new topographic map version at the scale of 1:50 000 it was decided to introduce a completely digital production line. A basic idea was to reduce the number of reproduction steps in the production of the final printing plates. Figure 2 illustrates the process used to produce the existing four colour map. In total map features are divided into 27 different feature separates.

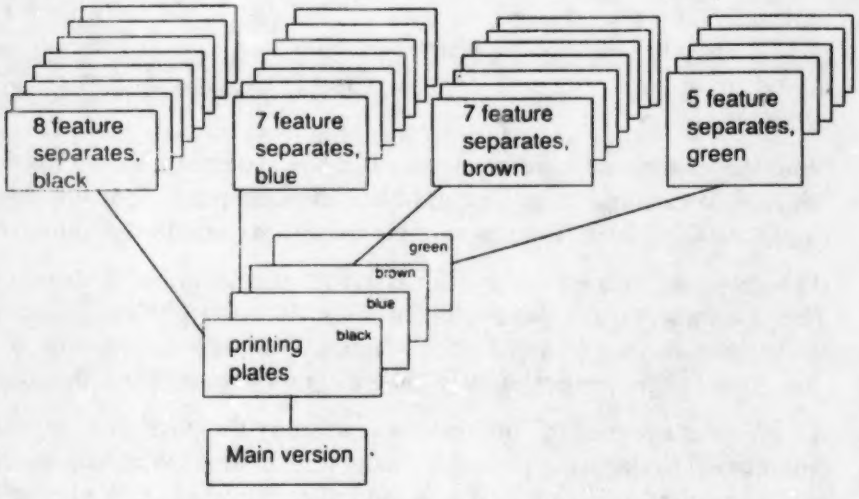


***Figure 2.** In the production of the four colour topographic map 27 different feature separates have been used. In a relatively complex reproduction process these separates are used to produce the four final printing negatives.*

For the new map series six colour printing is used. A rentention of traditional reproduction techniques for this map would result in the introduction of 11 more feature separates. This would, of course, also mean an even more complex reproduction scheme.

Figure 3 gives the basic principle of the production scheme for the new map. A fundamental part of the system is the cartographic database which includes a number of layers or "digital feature separates". These correspond, in principle, to the analogue separates of the traditional production process. However, in this model no analogue feature separates are outputted. This leads to a drastic decrease of the reproduction work as compared to the production model which so far has been used.

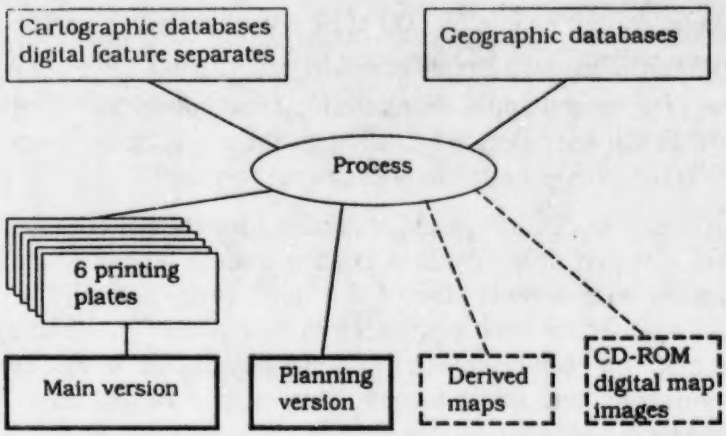


Figure 3. *The figure illustrates the digital production model used for the new topographic map series. No analogue feature separates are made. The printing negatives are produced and outputted in the Barco Mercator system.*

For the printing of the main map version only six printing negatives will be produced. In addition a black and white transparent version for planning purposes is outputted. The method also makes it possible to put out other types of derived maps. Another interesting possibility is to put out digital cartographic data in raster format for storage and distribution on CD-ROM.

Of course the establishment of the digital production line also included a choice of software and hardware for handling data acquisition, data base establishment and presentation. To a very large extent NLS makes use of an in-house developed software system, which basically consists of two parts. Thus a PC software, called AutoKa-PC, is used for data acquisition and data handling. For archival purposes the Geo Data Bank system, which is run on a mini computer system, has been developed. An important feature of this system is a possibility to mark all objects with birth dates. This makes it possible to find objects changed or added within a certain period of time.

Rasterised maps

Many GIS users have claimed their interest in using digital topographic maps in raster format in different applications. The demand for digital maps in raster format is particularly evident for military GIS applications as well as for transportation systems.

Already three years ago NLS produced a first CD-ROM containing i.a. the general map at the scale of 1:250 000, the so called Red Map, for the whole of Sweden. Raster data were obtained by scanning the feature separates of the map series with a pixel size of 0.1 mm. Each feature separate is stored on the compact disc in separate files of 1-bit data. There is also a file which contains the entire Red Map image with the same colouring as the printed map. The CD also contai-

ned a gazetteer with some 60 000 place names as well as administrative boarders and elevation data. This CD has been well received by the user community.

However, for several applications the map scale of 1:250 000 is not large enough. Thus, NLS has now decided to digitize the topographic maps at 1:50 000 and 1:100 000 for storage and delivery in raster format.

Two different production methods are used for the rasterised map at the scale of 1:50 000. For part of the country existing feature separates and printing originals are scanned with a pixel size of 0.1 mm. Thus, normally 13 black-and-white films are scanned for each map sheet. For the part of the country where the topographic map has been produced by completely digital methods existing vector data are converted into raster format. This method is also used for the 1:100 000 map series.

Rasterised data will normally be delivered on CD. In this case data are stored as a seamless set of data. About 200 map sheets can be stored on a CD.